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TIMBER THINNING PROJECT FOR UTILIZATION OF WOOD RESIDUE

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

TIMBER THINNING PROJECT FOR UTILIZATION OF WOOD RESIDUE

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ABSTRACT

This report discusses the results of an extensive field trial in western Montana in which precommercial forest thinnings were processed by a portable hog fuel chipper. The thinnings were done in 163 acres of second-growth ponderosa pine stands, all heavily infested by the mountain pine beetle. The study analyzed the production and costs of both the logging and chipping systems.

A three-person crew, consisting of one sawyer and two stackers, thinned an average of 121 trees per hour. Trees larger than six inches in diameter at breast height (DBH) were harvested with a commercial feller/buncher, which averaged 58 stems per net working hour in the selectively cut stands. Farm tractors, equipped with hydraulic log grapples attached to the three-point hitch, were used to remove the bunches of full trees from the woods to the landing. The tractors removed approximately 230 stems per net hour, with average skidding distances of 650 feet.

A Morbark Model 12 Chiparvestor* was used to process the entire tree (limbs, boles and needles) into chips suitable for hog fuel or raw material for alcohol production. Although individual stems ranged from one to eight inches DBH, the average stem contained approximately 2.2 cubic feet of wood. Per operational day, the chipper produced an average of 2.7 van loads of material, which was equivalent to 43.76 units, each containing 200 cubic feet. Based on a total of 150 van loads, the net chipping time per 40 foot van was 1.82 hours. Depending on the size of material processed, the chipping time ranged from 1.0 to 2.67 hours per van. In this largely dead and dying timber, the average 200 cubic foot unit weighed 2,528 pounds green weight.

* Mention of trade names does not constitute endorsement of the product by the cooperators in the project, but merely reflects the equipment available to conduct the study.

The combination of labor and equipment used for this project recovered an average of 16.58 units of hog fuel and 3,393 board feet Scribner Decimal C Rule per acre. On a per acre basis, the residual stands averaged 83 square feet of basal area, 252 stems, 116 cubic feet of precommercial timber and 1,951 board feet of commercial timber.

According to the machinery-labor rates and the product values detailed in this study, the profitability of the system depends primarily on the size of the average stem harvested and chipped. We have concluded that the break-even yield for the system is 16 units of hogfuel and 2,000 board feet of commercial timber per acre. Hogfuel revenue met total costs on one treatment area where we recovered 35 units per acre. The average stem size removed was 4.5 cubic feet - equivalent to a ponderosa pine tree 40 feet tall and six inches DBH.

In summary, we believe that the extended field trial has demonstrated the feasibility of this thinning/utilization system in our area. This approach to precommercial thinning will not only enable industry to use a largely untapped source of raw material, but will also allow the landowner to thin stands of small timber at a reduced or break-even cost.

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1. OBJECTIVE

This report presents the results of a study which determined the costs of chipping whole second-growth ponderosa pine thinnings in the Blackfoot River Valley of western Montana. The project actually consisted of two major parts. The first portion entailed gathering production/cost data for a full-tree thinning system in which the small trees were felled, stacked and removed to a central landing. In the second portion, the same type of data were compiled for a portable full-tree chipper that converted the small stems into hogfuel.

The second phase of the operation was made possible, in part, by the Alternative Renewable Energy Sources Program administered by the Energy Division of the Montana Department of Natural Resources and Conservation (DNRC). The specific purpose of this report is to fulfill contractual obligations under the terms of grant designation RAE 317-811. However, for two reasons, the scope of this report will be expanded beyond the full-tree chipping aspects to include the entire project. First, it is difficult, if not impossible, to discuss one phase of the study without extensive reference to the other. The logging phase is critical to the processing phase. For meaningful, accurate and useful results, the two phases of the operation must be viewed as one system. Second, in addition to the DNRC, other agencies, private corporations and individuals have requested the results of the entire study. Therefore, it seems appropriate to expand this report to include the whole project.

A correlative objective of the study was to examine logging and processing techniques which would be suitable for the smaller non-industrial private landowner - primarily the rancher and farmer. For this reason, we used logging techniques appropriate for landowners who may treat only limited acreage at one time. In addition, we employed farm machinery for logging wherever possible. The study could then complement information that is currently available for

for capital-intensive systems used by professional loggers on large-scale operations. Because the study was developed to provide information for the rancher/farmer with timberland holdings, a portion of the grant funds was used to develop construction drawings of a hydraulically operated log grapple designed to fit the three-point hitch mechanism of a conventional farm tractor.

II. PROJECT IMPLEMENTATION

1. Project Planning

In a sense, this project had its origin in 1968, when Mr. Bill Potter, a local rancher, began thinning and harvesting timber on his property and on adjacent ownerships. Potter became a part-time logger primarily because he was not satisfied with conventional logging operations, which left large amounts of debris in the woods. As a result, he began experimenting and modifying his farm machinery to remove the full trees from the woods. A further impetus to his efforts was the increasing infestation of his second-growth ponderosa pine stands by the mountain pine beetle. By 1975, the outbreak had spread to over 100 acres on his ranch, and he contacted the manager of the Lubrecht Experimental Forest for assistance in developing methods to use the dead timber. He had developed a successful system of thinning in which the full trees were removed from the stand with farm tractors, and he did not wish to continue burning the stems if beneficial uses could be developed for the material.

Thus, a cooperative effort was begun in the Blackfoot Valley by Potter, the Lubrecht Forest, Champion Timberlands and the Intermountain Experiment Station of the U.S. Forest Service to utilize the small ponderosa pine that had been killed by the mountain pine beetle. The merchantable trees were marketed for dimensional lumber, house logs and utility poles. However, the smaller trees, those under eight inches DBH, were very difficult to market economically. Although the traditional outlets for small material - posts, rails, barn poles and firewood - were tested, the additional handling necessary to manufacture these products was only marginally profitable, and transportation costs to the point of final use were often prohibitive. To compound the problem, we discovered that if these small infested trees were left in the woods, they would sustain and carry the beetle population. Therefore, they had to be removed to reduce the infestation effectively.

However, one approach to the use of the small dead timber did appear promising. Energy costs were rising, and many of the local wood products firms were using more hogfuel to supplement their energy needs. In addition, the Champion Packaging Division pulp mill west of Missoula was planning an expansion that would increase their hogfuel requirements beyond the present supply. Because a market seemed imminent, the cooperators decided to investigate the possibility of using portable chippers to convert the thinning material to hogfuel. Full-tree chipping technology was being used in other parts of the country and in our area, to a limited extent, to produce pulp chips. However, to our knowledge, no one in the intermountain West had attempted to produce hogfuel.

In 1977, the cooperators began to test four different full-tree chippers to determine the feasibility of producing hogfuel from small trees. Two of the machines were very large units designed to chip stems up to 22 inches in diameter. The third machine was a little hand-fed, trailer-mounted unit similar to those used by tree-trimming firms. The fourth chipper was small and mobile, yet self-feeding, and could effectively process trees 11 inches in diameter and smaller, with acceptable production rates.

The feasibility studies, which lasted from two days to one month, not only indicated machine efficiency but provided some data on potential yield. The tests showed that the very large machine and the small brush chipper were not suitable or cost effective for trees in the two to eight-inch DBH range. The largest chipper tested was an older Morbark Model 22 Chiparvestor. Although this machine was very slow and labor intensive and would not process material larger than five inches in diameter, it appeared to be a suitable compromise and was well suited to the material removed in the thinning operation. This unit was capable of chipping stems 11 inches in diameter, yet was small enough to be moved in the field with a farm tractor or with a medium weight truck

between jobs. In addition, it had the advantages of lower initial cost and reduced operating expenses. In one test, based on a total of 397 tons, the chipper produced a ton of material in 4.04 minutes from trees five inches DBH and smaller. When stems from five to eight inches DBH and the tops of larger trees were chipped, the production rate increased to an average of 3.7 minutes per ton, based on a total of 194 tons.

The preliminary tests also indicated that the second-growth ponderosa pine stands in our area should produce from 15 to 50 green weight tons of residue per acre, in addition to the commercial sawlogs. Twenty green tons per acre was the average yield from stands where only thinning was conducted. The residual stands contained 125 stems and from 3,000 to 10, 000 board feet per acre.

Because of the efforts of Potter and the other cooperators, the preliminary work demonstrated the potential of this thinning-utilization technique. However, we felt that these short-term trials did not produce enough reliable data that could be used to predict production costs and expected yields for similar operations. Therefore, the project participants decided that the next logical step would be to conduct an extended field trial of perhaps six months. After a period of discussion and negotiation, the cooperators agreed to assume the following major responsibilities:

Potter: Purchase or lease necessary equipment - Plan, thin/log the treatment areas - Keep daily records of all activities.

USFS: Develop the study plan - Aid Potter with record keeping and partial operational costs.

Champion Timberlands: Purchase the hogfuel - Provide necessary truck and trailer units to transport the hogfuel.

Lubrecht Forest: Provide overall project coordination - Collect stand data - Prepare reports - Conduct tours.

Western Montana Timber Utilization Group: This coalition of private non-industrial timberland owners would obtain and administer a DNRC grant, prepare reports and coordinate publicity and tours.

As stated previously, a major objective of the project was to test a system of thinning and chipping that a private non-industrial landowner could use most efficiently. For that reason, we wanted the kind of equipment that rancers or farmers may already own and that could be adapted for use in woods on gentle terrain. Any specialized machinery - particularly the chipper - must meet the criteria of availability, low initial cost, minimum operating expense and mobility. Mobility was important because we visualized, a chipping contractor servicing a number of landowners, each of whom would have a relatively small amount of raw material. Based on the previous tests, we also felt that a smaller chipper would be more economical for processing the precommercial trees removed in most thinnings.

Over the years, Potter had developed the full-tree removal system of thinning, and had either acquired, modified or constructed the machinery necessary for the logging phase of the operation. The cooperators were satisfied that his available equipment had proven its effectiveness and utility.

Potter used conventional chainsaws for the felling and bunching of trees less than five inches DBH. For the larger stems, he used one of two mechanical feller-bunchers. The primary machine is a Melroe Model 1075 Feller-Buncher, an 80-horsepower, hydrostatically driven unit equipped with a 16-inch shear attachment. The machine grips the tree, snips it off at the base and then lifts and places the stem in a bunch. Mechanical feller-bunchers are available commercially in a wide variety of makes, models and types to match a range of timber sizes and stand conditions.

Potter adapted a conventional Melroe Model 825 Steer-Skid Loader to fell and bunch trees less than eight inches diameter. He modified the machine with

guards on critical portions of the frame, additional operator protection and a homemade feller-buncher attachment. The unit worked very satisfactorily during its 50 hours of experimental use.

The basic skidding machines were conventional farm tractors that had been modified and adapted for woods use. Modifications included the installation of a "belly skid pan" and special guarding for the radiator, tire valve stems, power take-off unit and front axle tie rods. In addition, all the tractors were equipped with homemade log grapples which fastened to the three-point hitch. Since 1968, Potter has constructed and tested four different log grapples, all of which operated on the same basic principle. They fasten to the three-point hitch assembly of the tractor; however, a hydraulic cylinder replaces the solid bar on the top connector. The cylinder allows the operator to tilt the grapple back and forth. Separate hydraulic cylinders actuate the grapple teeth. The grapples are also equipped with a heeling bar located between the lower hitch connectors. The heeling bar enables the operator to back over the load, grapple the bunch, position the butts of the trees under the bar and tilt the load upward, raising the tops of the trees off the ground at a 20 to 30 degree angle. The advantage of this heeling technique will be discussed in a subsequent part of the report.

A portion of this grant was used to develop a set of engineered drawings with a material list so that interested landowners or contractors could acquire a similar unit. Potter used the grapple with the following diesel farm tractors: an Allis Chalmers Model 180, a Ford Model 7000 and a John Deere Model 2940 four-wheel drive.

Potter also owns a Model 440 John Deere rubber-tired skidder with a fixed grapple. He modified this machine by adding a heeling bar to the bang board and building a small winch-fairlead apparatus on top of the grapple support so that he could double his hauling capacity over long distances. The 440 was used in

the thinning operation either for long skids or on terrain that could not be negotiated with farm tractors. He also used the skidder to remove dead commercial timber from the thinned stands. For road construction and landing preparation, Potter used an older Model HD-6 crawler tractor.

Two basic pieces of machinery - tractor and chipper - were used in the processing phase of the operation. To feed the chipper either from prestacked piles or directly from the woods, Potter used the John Deere tractor with the grapples and front-end loader frame. He built two teeth that attached to the loader frame so that he could push material with the unit. A ball hitch was also welded to the loader frame, which enabled him to move the chipper with the tractor.

Acquisition of a full-tree chipper proved to be a difficult and time-consuming process. First, these are very specialized machines and, although more common in other parts of the country, they are relatively rare in the intermountain West. Second, only two companies, Strong Manufacturing and Morbark, manufacture portable chippers of the size appropriate for our operation. Third, neither firm had dealers in Montana or had a lease plan whereby the chipper could be rented for the duration of the project. Potter then had no option but to purchase a unit, a factory-reconditioned Morbark Model 12, at the cost of $50,000. (Morbark has since discontinued manufacture of this model.)

PROJECT IMPLEMENTATION

Study Area Description

The study area is located in the Blackfoot River Valley of western Montana, approximately 40 miles northeast of Missoula. The study was conducted on ten separate treatment blocks which totaled 163.1 acres. The units varied in size from 2.6 to 39.2 acres, principal owners being Bill Potter (89.6 acres), Lindbergh Cattle Company (55.5 acres) and Champion Timberlands (18.0 acres).

The terrain was similar on all ten plots. In general, the topography was gentle to moderately sloping, with a maximum slope of 40 percent and an average slope of 10 percent. This type of ground was chosen for two reasons. First, the feller-bunchers and farm tractors are unable to work on steeper slopes. Second, the rolling, bench-foothill topography is typical of much of the privately owned ranchland in western Montana.

The timber stands were all predominately second-growth ponderosa pine. Some blocks were comprised of primarily precommercial-size trees, while others contained a wide range of tree sizes. The average stand age was approximately 70 years, and the majority of the trees removed were in the 40- to 80-year age class. All the stands were infested with mountain pine beetle and more than 90 percent of the stems were either dead or dying in some units. All the dead and dying stems two inches DBH and larger were removed from the stand in each unit.

Table 1 gives a summary of pertinent average stand data for the blocks before and after treatment. One unit of 39.2 acres was excluded from the data because the harvesting method on this block was significantly different than the other areas. Primarily commercial timber was removed, and no thinning took place. The information on the residual stands was developed from a variable plot cruise of all the units subsequent to treatment. The commercial timber removed from all the areas was scaled, and these figures were added to the cruise

volumes to arrive at the pretreatment values. The pretreatment cubic foot volumes were determined by converting the amount of hogfuel removed to solid cubic foot volumes and adding these to the appropriate cruise values. A factor of 2.5 chipped volume to 1.0 solid volume was used in the conversion process. In addition, an allowance was made for tops, limbs and needles. Because of this conversion process, the precommercial cubic foot volumes before thinning must be considered an approximate value.

PROJECT IMPLEMENTATION

Description of the Full-Tree Logging and Chipping Systems

It is essential to mention a basic premise of this harvesting and utilization technique: the need for a closely coordinated, systematic approach in the entire operation from stump to chipper. Small stem handling is costly, and each step in the total process is critical to effective overall flow; mishandling in one phase has a serious ripple effect throughout the entire operation. This system requires cooperation among crew members, and every individual must be familiar with all phases of the logging and processing. Unlike many conventional logging operations, in which people are paid on the basis of their individual production, this approach requires that the entire crew share in the total output. Therefore, with proper training and a payment schedule based on total system output, each crew member has more incentive to make the entire operation run efficiently.

The full-tree logging and chipping system used in this study has three major components: felling-bunching, skidding and processing (which includes chipping). Before examining the system in detail, it may be helpful to briefly summarize the logging method. Potter developed this technique to thin and salvage log all-aged stands of ponderosa pine that were infested with the mountain pine beetle. His basic approach differs somewhat from the more traditional method, in which larger trees are harvested before thinning begins. Potter thins the stand before any commercial timber is removed. He removes the stems from the smaller trees then progresses through the larger.

In the first step, trees less than five inches DBH are generally hand felled and piled into bunches for removal to a central landing by a grapple-equipped farm tractor. In most cases, the bunches are cold decked (pre-stacked) at the landing for future chipping. This first step prepares the stand for entry and enables more efficient operation during the second phase, in which

dead or designated trees from six to fourteen inches DBH are harvested with the Melroe Model 1075 Feller-Buncher. If stand conditions permit, trees are sorted in the woods by size into precommercial and commercial piles. In other instances, the various sized trees are piled together. The bunches are then skidded to a landing by either the farm tractors or the rubber-tired skidder for processing into chips or logs. The third step of the operation consists of directionally hand falling timber too large for the feller-buncher into openings which were purposely created in the previous steps. If there are relatively few trees in the stand, steps two and three are combined. The larger trees are also skidded full length to the landing.

The basic logging system then consists of one or more stand entries, the directional felling and stacking of the stems into bunches, and the removal of the piles to a central processing area by a grapple skidding machine. Because the number of stand entries depends on the size range of trees to be removed, a precommercial thinning may consist of a single entry. However, it is important to note that the smaller stems are removed first and that the size of the machinery is correlated to the size of the tree.

In the paragraphs that follow, we will analyze the three basic phases of the entire operation as they pertained to the individual treatment blocks. Although the three major phases of the total system will be presented separately, many of the steps can occur simultaneously, depending on specific stand conditions. A summary of the methods used on each treatment block is presented in Table 2.

At the onset of the study, the cooperators did not attempt to narrowly define the exact logging and processing technique for each block. Rather, because this was to be an operational test, we felt that as Potter gained more experience with the logging and chipping system, he should be free to improvise and improve his methods as the study progressed.

The felling and bunching step is the first and the most important phase of the logging operation. The purpose of this system is to remove as many small stems and as much debris from the stand as practical. Therefore, to a large degree, felling and bunching dictates the effectiveness of the entire operation.

Potter's felling and bunching technique is guided by three basic principles. First, the felling and bunching of the stems is sequential, beginning with the smaller stems and progressing to the larger trees. By reducing breakage, waste and handling of short chunks, this approach allows the operator to recover the maximum amount of material. In addition, the small machinery can move more quickly through the stand when this material is removed. Second, it is absolutely imperative that the trees be directionally felled. This principle applies to all sizes of trees. Usually trees less than five inches DBH can be sawn and stacked by hand. Larger stems, when sawn by hand, can be felled directionally through proper placement of the undercut and use of wedges or felling aids. A major advantage of the mechanical feller-buncher is that this unit can fell, lift, carry and bunch the larger trees with minimal damage to the residual stand. Of course, grapple skidding is most efficient when the stems are pre-piled. Third, the felling and bunching is done in a fanshaped pattern radiating out from the landing area. After the skid trails are cleared, the felling begins from the back of the stand so that the bunches can be placed in a veined pattern to the main skid trails. This felling and bunching techniques does not damage standing trees and increases skidding production.

In most of the treatment blocks, the smaller stems were hand felled and bunched by a three-person crew consisting of one sawyer and two stackers. We have found this crew composition to be the most efficient. Blocks 1,2,3,4,7 and 8 and a portion of 6 were all treated in this manner.

To alleviate some of the physical labor associated with hand felling and stacking, a homemade feller-buncher head was constructed for the Model 825

Melroe Bobcat Steer-Skid Loader. In Block 9, the Model 825 and a second person acting as a sawyer/stacker felled all trees eight inches DBH and smaller. The production rates of this system were similar to those of the three-person crew. A portion of Block 6, which contained many trees from five to eight inches DBH, were felled by the Melroe Bobcat 1075 working with a sawyer/stacker. This system also appeared promising. Based on these trials, Potter used both machines in Block 10 to fell all the trees less than 15 inches DBH. Both the Models 825 and 1075 were accompanied by a sawyer/stacker who fell and bunched the leaning trees or those which were not accessible to the machine.

With the exception of Blocks 1 and 9, the trees from approximately six to fifteen inches DBH were felled and bunched with the 1075. Because of steep slopes and the dense residual stand, the larger trees on Block 1 were felled by hand. Those occassional trees that were larger than the capacity of the 1075 were directionally felled by hand into openings prepared during the first cuttings. The 1075 could cut larger trees if notches were first sawn in them to allow the shear head to encircle the bole.

The size of the bunches depended on a number of factors. The most important consideration was the carrying capacity of the particular skidder used to remove the material. As a rule, it was most efficient to match bunch size with the skidder capacity. However, this guideline was tempered by both the distance that the trees had to be moved and the difficulty of moving the stems - particularly by hand. Whenever feasible, the feller-buncher sorted the trees into piles according to size or end product. Presizing the bunches in the woods significantly reduced sorting time at the landing.

As indicated previously, a variety of machines were used to skid the bunches of trees from the woods to the landing. As a general rule, the farm tractors skidded those piles which were 600 feet or closer to the landing.

On those blocks where all the trees were removed prior to chipping, the tractors also skidded the commercial sized trees within the same distance. The John Deere Model 440 with a fixed grapple skidded bunches from distances over 600 feet (2,000 feet on Block 4) or from terrain too difficult for the farm tractors. The advantages of using hydraulic grapples as compared to chokers is self-explanatory. The winch assembly described earlier in the report also enabled Potter to bring in double loads with the skidder and increased payload efficiency on the long skids.

A unique feature of Potter's grapple skidders is the addition of a heeling bar. The heeling bar is important for two reasons. First, in the woods, the operator can pick up a small bunch of trees, heel it and back up to a second pile so he can skid both to the landing in one trip. Second, at the landing, the material can be heeled and stacked in a "shingle pile," a system which has definite advantages for feeding the chipper, as will be described later in this section.

The skidding was closely linked to the felling-bunching phase of the operation and therefore also moved in sequence from smaller through larger trees. In most cases, the small stems were removed from the stand before the felling and bunching of larger stems. On some occasions the skidder worked in conjunction with the felling crew, while in others the entire area was felled and bunched prior to removal. The specific approach depended primarily on size, number and spatial arrangement of the bunches. At minimum, the piles in the main skid trails were removed from the woods first. The bunches of small stems in Blocks 1,2,3,and 4 and a portion of 6 and 7 were all removed and stacked on the landing before harvest of the larger precommercial and commercial trees. In the remaining blocks, the bunches of small stems were "hot logged" directly from the woods to the chipper for processing.

After the larger trees were felled and bunched, the piles would be skidded directly from the woods to the landing. The felling-bunching were either completed

before skidding or the two operations proceeded simultaneously, depending on the amount of materials to be removed, the skid distances and the rate of processing on the landing. Once again, Potter always attempted to match equipment capability with tree size.

The third and final step of the full-tree logging system is the processing of the trees at the landing. Because the stands harvested in this study contained a range of tree sizes, any stem that contained a 16-foot-long log with an inside bark top diamter of six inches was considered merchantable. The commercial trees were limbed and bucked by hand. The resulting logs were then sorted and decked for either pulpwood or sawlogs. The tops of the commercial trees and all trees that did not contain a log were chipped. On Blocks 1,2 and 3, all the trees were processed and the chippable material was predecked. In the other blocks, the tops of the commercial trees were moved directly from the processing area to the chipper.

The chipping system consisted of three people and two machines. The basic unit was the Model 12 Morbark Chiparvestor. This machine, powered by a 230-horsepower John Deere diesel engine, is capable of chipping trees up to 11½ inches in diameter. However, it is most efficient when the trees are less than nine inches in diameter. The machine is equipped with a slide rail grapple and four power feed rolls. The grapple pulls the stems up a skid pan into the power rolls, which feed the material against a rotating flywheel. The flywheel has two 12-inch knives, which chip the stems against an anvil. An experienced operator can overlap the trees coming into the feed rolls in such a manner that the chipper produces a constant flow of material.

The slide rail grapple is not designed to lift entire stems but rather to reach out and pull the material into the feed rolls. Therefore, it is necessary to position the piles in front of the skid pan and in line with the throat of the chipper. In previous experiments, we had tested both a front-end loader

and a heel-boom type log loader for positioning the stems. However, both machines proved unsatisfactory because it was very difficult to keep the butts of the trees compressed for easy access by the chipper grapple. The most efficient method of positioning the bunches proved to be the same farm tractor that was used to skid the material from the woods. For feeding the chipper, the tractor was equipped with short pusher teeth mounted on the front-end loader frame. The tractor operator would pull the stems alongside the infeed chute of the chipper, drop the load and then push them into position. Using pusher teeth rather than a blade minimized dirt accumulation in the pile and thereby reduced knife wear. The John Deere Model 2940 was used to feed the chipper.

The labor component of the chipping system consisted of three people: a chipper operator, a tractor operator and a handyman. The functions of the equipment operators are self-explanatory. The handyman, as the term implies, fulfilled a variety of functions that made the entire operation proceed more smoothly. The duties included positioning the chipper and chip vans, cleaning debris away from the chipper, sawing extremely crooked material so that it fed more easily into the chipper, and limbing/bucking commercial trees. Cleaning debris from beneath the feed rolls was a particularly critical function. Bark, branches and pieces of wood would fall through a gap between the bottom feed roll and the rotating disc that contained the chipper knives. If the material was not removed periodically, it would accumulate, become entangled between the chain and sproket of the lower feed roll and break the chain. The accumulation of material in front of the skid pan was easily pushed aside with the tractor.

The three-person crew switched jobs after each van load. Alternating duties provided variety, lessened fatigue and, most important, enabled each crew member to become very familiar with the total chipping system. Teamwork and cooperation between crew members was enhanced significantly.

Potter used three basic approaches to combine the logging and the chipping steps into a total operation. First, he predecked all the material at the landing for chipping at the conclusion of the logging operation. In the second method, the material was moved directly from the woods to the chipper. Third, he used cominations of the "cold decking" and "hot logging" approach.

With the cold decking method, the trees must be piled in a manner that facilitates efficient movement from the stock pile to the chipper. In previous experiments, the cooperators had tested different methods of piling the thinning slash. In our first trial, the bunches were stacked with a front-end loader in a windrow that was 18 feet wide, 240 feet long and 9 feet tall. Although this pile yielded 120 tons of chipped material, a log loader was needed to remove the trees and to rebuild grapple loads for skidding to the chipper - a time consuming and costly process. In another test, the bunches were decked with a skidder blade and then moved to the chipper with a front-end loader. However, both approaches had some basic disadvantages. Both required an additional machine to either deck the material or move it to the chipper. A large landing was necessary to store the piles and also to provide maneuvering space for the front-end loader. In winter logging, snow accumulated on the decks, and the bottom row of trees full length of the pile froze to the ground. Finally, when using a skidder blade, it was difficult to keep dirt out of the decks.

To overcome these problems, Potter developed a "shingle stack" method of cold decking the bunches of small stems. The trees were skidded from the woods, heeled with the tops off the ground at a 20 to 30 degree angle and backed into the stack. Succeeding bunches then overlapped the previous material, and only the butts of the trees were on the ground. This method overcame all the difficulties of the other systems: The same machine can skid, deck and feed the chipper; the decks can be made in smaller openings or on the sides of the road; the piles are dirt free; only the first row of bunches is completely on the ground, and the porcupine configuration of the pile appears to eliminate excessive snow accumulation.

The shingled method of decking has some additional advantages. Both small trees and tops of commercial trees can be piled in this manner, which adds flexibility to the total operation. This system also maintains the integrity of the bunches from the woods to the chipper - the trees in a bunch stay together. The stack can be taken apart in the reverse order that it was constructed without the stem tangling that was prevalent with the other methods. The trees can be moved in a straight line when the stacks are built in front of the chipper, which reduces landing size requirements.

As noted previously, a combination of methods was used to coordinate the chipping and logging systems. On Blocks 1,2 and 3, all the material was cold decked before the chipping operation. This was necessitated by a later than anticipated delivery of the chipper, and Potter wanted to continue with his operations. On Blocks 4 and 7 and a portion of 6, the hand-thinned material was removed and stacked at the landing. The larger stems were felled, bunched and left in the woods. Then the piles were skidded directly to the chipper after an intermediate processing step for the removal of commercial logs. On a 10.2-acre portion of Block 6 and on Blocks 8 through 10, all classes of material wre hot logged directly from the woods to the chipper. Area 5 was not hand thinned and only larger stems predominately sawlog trees, were harvested.

All three approaches - cold decking, hot logging or a combination - worked well and demonstrated that the entire system can be adapted to a wide range of conditions. However, each method had inherent advantages and disadvantages. Although cold decking requires an extra step in the operation, it has the advantages of maximum flexibility, reduced landing space and fewest equipment requirements. This system would appear to have the widest application for a chipping contractor who services a number of thinning operations. The logging and chipping phases can be completely separated.

The major advantage of the hot logging systems is elimination of the decking step. However, a larger crew and more equipment are needed to fell and bunch, skid, process sawlogs and chip the material in one operation. Good coordination is necessary to ensure a steady flow of material through the chipper, and a major equipment breakdown has the potential of shutting down a more costly operation.

In a thinning-logging situation, the combination of cold decking and hot logging has some distinct advantages. When the smaller stems are removed from the stand, there is more opportunity to sort the larger trees in the woods by commercial and precommercial sizes. The chipper (when it can be fed from either the predecked or hot logged material) is not dependent on a single source of material. In addition, if the chipper were to break down, the crew could continue to process larger trees and stockpile the residue for future chipping. Using this system on Block 7, Potter realized his greatest single day's production on the study: A five-person crew produced four van loads of hogfuel and 18,000 board feet of sawlogs.

Handling of the hogfuel is the last item to be considered in the chipping system. In this study, the chipper blew all the material directly into standard 40-foot-long chip vans supplied by Champion Timberlands. Holes for the outfeed chute of the chipper were cut into the rear doors of the vans, which were used as set-out trailers. The centrifigal action of the chipper disc on the Model 12 was sufficient to blow the material to the front of the vans. A hauling tractor would spot an empty van on the landing and pick up a loaded trailer for the 45-mile trip to the Champion Packaging Pulp Mill west of Missoula. At this distance from the mill, the one tractor was able to haul an average of three vans per day. The John Deere farm tractor moved the chipper between vans, and the transfer time averaged 20 minutes. When using highway tractors and 40-foot vans, adequate turnaround room must be provided at or near the landing. In addition, all haul

roads must have corners wider than those required for logging trucks. It is critical to block carefully the legs of the van to prevent settling during filling and to maintain proper height for easy hook-up by the tractor.

In previous experiments, we had tested both blowing the chips on the ground for later reload and keeping the tractor-trailer unit in position during loading. Cost and large space requirements were the chief disadvantages of the reload system. Although filling the van with the tractor attached did eliminate van transfer, this approach also had some distinct disadvantages. Foremost was the unproductive time of the driver and tractor unit during loading. The small chipper was unable to fill a van fast enough to justify this technique. However, the method did prove feasible when a large chipper processed bigger trees and the van loading times were from 20 to 30 minutes. This system also requires more tractor-van units so that the chipper can operate at full capacity.

The use of set-out trailers eliminated the disadvantages of the other systems and gave Potter the maximum flexibility in his operation. If pulpwood cutting were combined with chipping, set-out trailers could also be used for pulp logs. This would eliminate the log decking step and enable the same tractor to service both the vans and log trailers.

PRODUCTION DATA

Stand and Production Data

Three major types of records were kept in this study: stand data, production rates and yield information. We combined these records with labor-machinery costs and end product values to evaluate the system's economic feasibility, which will be presented in a subsequent portion of this report. The basic principle underlying the record system was to generate reliable data that would benefit other people interested in using this full-tree harvesting-utilization system.

In the following paragraphs, we will discuss each data grouping in detail, including a summary of the pertinent results in table form. The tables will present the information as a weighted average and a corresponding range of values. The weighted average for a specific item was obtained from the entire study. The range of values was obtained from the averages for each treatment block. It is important to note that the range-of-values information does not represent the extremes of single or isolated measurements but are the spread of averages from the individual treatment blocks. Because Block 5 was essentially a commercial salvage cutting with no thinning, the data from this area are not reflected in the tables.

The stand data were developed so that we could describe the treatment blocks before and after the operation. The information will also enable others to evaluate the application of these techniques for their individual situations. The stand data presented in Table 1 are located in a preceeding section of the report. Because the blocks were not cruised before thinning, we are unable to list pretreatment stand basal areas. However, the University of Montana School of Forestry, is currently conducting a thinning-chipping study in which stands are being thinned to different spacing levels. Complete basal area data for the various treatments are available from Lubrecht Forest staff.

While gathering production data, we wanted to monitor, as closely as possible, Potter's logging system without interfering with his operational

decisions. The cooperators wanted Potter to modify and improve techniques as he felt necessary. The project budget did not provide for special personnel to do a conventional time-motion study on all the blocks. However, the cooperators decided that system production rates for all areas - albeit of a more general nature - would most accurately reflect those found in an operational situation. For these reasons, records were kept by the individuals doing the work. The data were normally compiled twice a day, once at lunch and again at the close of work. The individual crew members recorded the time they spent on a particular function, in addition to any machine breakdown time that occurred. With the exception of chipping, they did not attempt to detail other non-productive time such as travel, rest breaks or routine equipment maintenance. The crew serviced equipment for approximately 30 minutes each weekday and three hours on Saturday morning.

Potter's crew recorded production rates for three functions - felling and bunching, skidding and processing - in three different size classes of trees. The stem size categories were: five inches DBH and smaller, six to fifteen inches DBH, and sixteen inches DBH and greater. The method of felling and bunching was the primary factor in the delineation of these classes. With the major exception of Blocks 8 through 10, the three functions were completed on the trees in one size class at a time. Chipping was the only function in which no attempt was made to differentiate between size classes because it simply was not practical to separate the small stems from the tops of commercial trees and chip each group independently. However, on a block basis, we did record the number of pieces per category that contributed to the total volume of chipped material.

Table 3 contains a summary of the production data by function and material size class. The information was averaged from those blocks in which the particular techniques were used. The results for the two smaller size classes are

given in number of pieces per hour because we feel that this unit will be most beneficial to potential users of the data; board feet Scribner Rule is the most common method for measuring commercial timber. The chipped material was measured both by green ton weight and units. In this case, a unit is 200 cubic feet of chipped material, irrespective of weight.

Three different units of time are indicated in the chipping production data. Net chipping time is when the machine was actually processing material. Gross chipping time includes down time for repairing minor machine problems, cleaning debris from the unit and waiting for raw material. Total gross running time for the chipper was 274 hours and total net time was 254 hours. System days reflects all the time the chipper was operating in the field, including down time for alternating vans, changing chipper knives, moving to new landings and so forth. This figure also encompasses the non-productive time related to the maximum hauling capacity of three loads per day. The chipper operated for 51 system days on the project. Net chipping time was approximately 70 percent of the system time.

Table 4 lists the average per-acre yields of chipped material and sawlogs for the study. In addition, some relationships between various expressions of yield are presented. All the commercial sawlogs from the treatment blocks were scaled (measured.) Each van of chipped material was weighed, and selected loads were sampled to determine the weight-per-cubic-foot relationship. From this measurement, the number of 200 cubic-foot units per van - and therefore per block - was established. The relatively light weight per unit indicates that a large amount of dead timber was chipped and also that much of the material was predecked an average of three months before processing. In those cases where green trees were hot logged and chipped directly from the stump, the average unit weighed approximately 3,000 pounds. We determined the average piece size by dividing the total cubic feet of chipped material recovered from the block

by the total pieces (including tops of commercial trees) removed from the unit. A factor of 2.5 was used to convert the cubic feet of chipped material to cubic feet of solid material. For example, 100 cubic feet of hogfuel equaled 40 cubic feet of solid wood.

Energy Use and Yield Analysis

In this section we present the average fuel consumption figures by hour and by unit of product for the various machines. These data are then compared to the expected energy yields of the chipped material. Finally, we compare the energy requirements of this system to one utilizing higher production machinery.

A. The average fuel consumption per hour for the various machines used in Bill Potter's operation were:

AC 180 Farm Tractor	.78 gal/hr
Ford 7000 Farm Tractor	.78 gal/hr
JD2940 Farm Tractor	1.10 gal/hr
JD 440 Skidder	1.37 gal/hr
Model 12 Chipper	6.05 gal/hr
825 Bobcat	.66 gal/hr
1075 Bobcat	1.02 gal/hr

B. The average fuel consumption per unit of chips for the different steps of Bill Potter's operation are:

Felling & Bunching	
(Small & large Bobcat Feller Buncher	.44 gal/unit
Skidding (John Deere 440G & 2940)	.33 gal/unit
Chipping (Morbark Model 12)	.69 gal/unit
(John Deere 2940 tractor)	.13 gal/unit
Total	1.59 gal/unit

C. Energy Value of Chipped Material

There were 2399.48 units of chips removed from the study areas. These units weighed a total of 6,146,500 pounds and averaged 2562 pounds each.

The thinned stands averaged 90 percent ponderosa pine and 10 percent Douglas-fir. This would give:

5,531,886 lbs ponderosa pine
614,654 Douglas-fir

Champion International and the Forest Service feel that logging and thinning residue will average about 45 percent moisture content. This figure could vary according to species, climate and time of year.

According to the Forest Service Forest Products Laboratory the heating value for the two species of timber chipped on this project is:

	Dry Heating Value	Percent Moisture	Net Heating Value
Douglas-fir	9035 BTU/lb	45	4969 BTU/lb
Ponderosa pine	9100 BTU/lb	45	5005 BTU/lb

The total average usable heating value for the chipped material is:

Ponderosa pine	5,531,886lb x 5005 BTU/lb =	27,687,089,430
Douglas-fir	614,654lb x 4969 BTU/lb =	3,054,215,726
		30,741,305,156 BTUs

D. This section will compare the amount of energy used to process the stems to the expected energy from the chipped material.

As shown in item B of this section, it took 1.59 gallons of diesel to process one unit of chipped material:

1.59 gal/unit x 133,332 BTUs/gal = 211,998 BTUs/unit

This figure represents the approximate energy it took to fell, bunch, skid and chip one unit of chipped material.

Chips Net Energy Value:
A unit (2562 lbs) would average

Ponderosa pine	2306 lb x 5005 BTU =	11,541,530 BTUs
Douglas-fir	256 lb x 4969 BTU =	1,272,064 BTUs
	Total Net BTUs/unit =	12,813,594

When we compare the BTUs of energy necessary to process one unit of chipped material to the energy derived from that unit of chipped material, we show a 604+ percent energy gain.

If we were to look at the BTUs of energy it would take to process the thinning residue and then deliver it to the pulp mill at Frenchtown, the figures would be:

Processing	1.59	gal/unit
Trucking	1.29	gal/unit*
	2.88	gal/unit
	x 133,332	BTUs/gal
	383,996	BTUs/unit

When compared to the energy value of the chips, we still show a net energy gain of over 334+ percent.

E. The Research Study

Technical and Economic Aspects of Harvesting Dead Lodgepole Pine for Energy, by John W. Henley gives us a means of comparing the energy use of commercial sized equipment to the farm sized equipment used in our project.

During Mr. Henley's study, cutting units on timber sales in Oregon's Umatilla and Wallowa-Whitman national forests were harvested. The units ranged from about 15 to 35 acres in size. All of the lodgepole

* This was figured on a 90-mile round trip, with the truck averaging 4.35 miles/gallon and the trailer holding 16 units of chips.

pine trees, green as well as dead, were clearcut. The average diameter at breast height of the lodgepole stands ranged from five to nine inches. Most of the lodgepole pine had been dead for four to five years.

The approximate diesel fuel requirements per unit of chips are:

John Deere 544B/Rome feller-buncher
.40 gal/unit
Catepillar 518 & Clark 667 skidders with
Esco 36 grapples
.46 gal/unit
Morbark Model 18 and Model 22 chippers
.71 gal/unit

Total = 1.57 gal/unit

This thinning study showed a net fuel usage of .02 gallons/unit less than our thinning study.

This lower consumption rate/unit results from the larger size classes of timber processed in this study and the ability of the equipment to handle more and larger stems.

System Cost

There are many factors which affect the cost of a thinning or logging operation. These include the objectives of the landowner, timber stand characteristics, volume harvested, method of logging, size and type of machinery used and equipment-labor rates. In this study, many of the variables were fixed or predetermined by Potter. For example, his objective was to remove primarily trees that had been either killed by or infested with the mountain pine beetle. He cut green trees only to get access to the dead and dying timber. In harvesting, he wanted to minimize damage to the residual stand. After the mountain pine beetle infestation was controlled on his entire ownership, Potter planned to re-enter the areas and harvest enough green trees to accelerate stand growth. Whenever possible, Potter also used his full-tree logging system, which emphasized the use of adapted farm machinery and ranch labor.

The two major cost variables to be determined for this report were machinery and labor rates. Equipment rates were developed with standard techniques that considered factors such as current and salvage value of the machine, depreciation schedules and assumed maintenance costs. The hourly rates, both fixed and variable, for the equipment used in the study are presented in Table 5. The small steer-skid loader with the homemade feller-buncher attachment and the grapple-equipped tractors were considered farm machinery. We assumed that farm machinery would have longer depreciation schedules and lower maintenance costs than the more sophisticated commercial logging equipment. When determining the rates for the specialized logging machinery - 1070 Feller-Buncher, JD 440 skidder and Model 12 Chiparvestor- we assumed that they would be operated by a prudent owner who was sensitive to machine maintenance. Although we feel that the rates are realistic, they may be lower than those charged by a contractor who does not personally operate and maintain the equipment.

Labor rates were also developed under the assumption that much of the hand-thinning work and operation of the farm machinery would be done by the timberland owner or by contract thinning crews. By contrast, professional woods workers would do the major portion of the commercial timber harvesting and chipping, including operation of the 1075 F/B, JD 440 skidder and Model 12 Chiparvestor. Labor rates for the various types of work will vary widely among individuals, agencies and corporations. At one extreme may be landowners who do not charge personal labor against the cost of thinning. At the other extreme, it is not unusual for private corporations to pay thinning crews a base wage of $8.00 per hour or a total of $10.00 per hour when fringe benefits are included. State of Montana thinning crew members receive $4.81 per hour. The State must also include a fringe benefit package of 20 percent, which brings the total labor cost to $5.71 per hour. For this study, we have chosen a median rate of $7.50 per hour total labor costs for thinning crew members and farm labor. For the professional loggers, we used a total wage cost, including fringe benefits, of $12.00 per hour.

Using the machinery and labor rates explained previously, Table 6 presents the logging and processing hourly rates by the various functions.

By applying the hourly rates presented in Table 6 to the production data presented in Table 3, we determined the production costs by function and material size class. Table 7 contains this information. We want to remind the reader that the production figures for the functions of felling and bunching, skidding and processing do not include time for rest breaks or routine equipment maintenance. In those cases where Table 3 lists production by board feet per hour, the equivalent costs in Table 7 are given in thousands of board feet (MBF). We calculated system day costs on the basis of a seven-hour working day because the study was conducted in the late fall and winter months, and Potter had daily ranch chores which limited his logging time.

Economic Evaluation of Full-Tree Chipping

In the preceeding section, we listed costs based on assumed equipment and labor rates for the various parts of the logging-utilization system. To complement these figures, we must also determine values for hogfuel and logs. For this analysis, the value of hogfuel blown into a van is $15.00 per 200 cubic-foot unit. Potter sorted logs into two categories: pulplogs and sawlogs. Decked pulplogs - generally smaller material which was too checked for sawing into lumber - were valued at $80.00 per thousand board feet (MBF). The decked value of large, sound logs was $160.00 per thousand board feet. Although hogfuel and log prices will vary greatly depending on local market situations, we feel that these values are applicable. It is important to note that the evaluation does not consider either the cost of hauling the material to a mill or the increased value of the delivered products.

Table 8 gives a summary of the volume removed and costs and income for the individual treatment blocks on a per acre basis. The volume data is included as a reference to help explain the cost and revenue figures. Because primarily sawtimber was removed from Block 5, this data was once again excluded from the table. The costs for the three different size classes of material include total costs for felling and bunching, skidding and processing. The chipping costs are based on the number of system days required to process all the material from the unit.

The purpose of presenting this rather detailed information is not to compare units specifically but to demonstrate patterns and general conclusions. It would be statistically invalid to compare absolute costs between areas because each unit was logged with a particular system of equipment and labor. In addition, the number and size of trees were different in each unit as was the mix of products recovered.

We believe that at least five general observations on the economic

aspects of full-tree harvesting and chipping can be drawn from Table 8. They are as follows:

1. As expected, the per acre logging costs reflect not only the number of stems cut but also the average size of the tree. For example, although 807 trees per acre were cut in Block 1, the average size of each stem was small, and this unit therefore had the lowest per acre logging cost. By contrast, Block 6 had a very high logging cost, but the fewest number of trees removed per acre. However, a greater percentage of the stems were merchantable.
2. Likewise, the chipping costs closely correlate with the number of units processed per acre. However, the size of the average piece is also a factor. It cost approximately 9.9¢ to chip a cubic foot of material on Block 8, whereas the cost per cubic foot was 14.0¢ in Block 1. To obtain these figures, we divided the total chipping cost by the number of pieces times the average piece size.
3. In all cases, the value of the hogfuel was higher than the cost of chipping the material. Only in Blocks 8 and 9, where the average piece size was five and four cubic feet respectively, were the total costs of the operation met or exceeded by the value of the hogfuel.
4. With the exception of Block 10, which contained a high percentage of trees in the six- to eight-inch DBH range, log values significantly exceeded logging costs for commercial trees. Although Potter did not specifically test this conclusion, we believe that it is more profitable to maufacture higher valued logs rather than hogfuel from commercial trees.
5. It appears that this operation can be a break-even proposition in two general instances. First, if hogfuel only is produced, the average stem should contain a minimum of four to five cubic feet. This is

approximately equivalent to a ponderosa pine six inches DBH and 40 feet tall. Second, if the average piece is two to three cubic feet (four-inch DBH tree), commercial timber must be removed to subsidize the operation. Potter uses two thousand board feet per acre as a rule of thumb for his thinning-salvage logging. The data from Block 3 appears to substantiate his conclusion.

When developing the logging costs for the various size classes of material, we noted an interesting relationship which is not depicted in Table 8. In the small tree category, the weighted average felling and bunching cost per acre was approximately twice that of the skidding cost: $101 per acre versus $47 per acre. However, in the six- to fifteen- inch DBH range, the cost relationship was reversed: $34 per acre for felling and bunching and $43 per acre for skidding. The cost data in Table 7 also confirm these observations. However, these relationships were not unexpected because Potter fells and bunches the small stems to aid skidding as much as possible. With the smaller trees removed, Potter can then maneuver through the stand more efficiently with the 1075 to harvest the larger stems. In addition, lower cost farm tractors are generally used to skid the small trees, and the 440 skidder is used to remove the larger stems.

Although full-tree thinning is expensive, landowners can minimize costs in a number of ways. First, the operator must have a very well coordinated, yet flexible logging plan. Second, the size of the equipment should match closely the size of the timber harvested. Finally, the landowner may choose either to use this system only in precommercial stands or to avoid removing very small stems from the woods.

Environmental Aspects

We did not research or collect any data on soil nutrient requirements, soil erosion or other environmental aspects which may or may not be affected by this thinning and utilization method.

It should be noted, however, that during the process of felling, bunching and skidding, a large majority of the needles and smaller limbs fall off or are broken off. In most cases, this material will form a mat on the ground two to four inches deep. This layer of material should keep any soil erosion to a minimum. A landowner could have a problem with soil erosion on the skid trails and logging roads. Bill Potter alleviates this problem by seeding these areas down with a variety of intermediate wheatgrass using a no-till drill.

Forest Service research has shown that the greatest concentration of nutrients present in a tree can be found in the needles and branches two inches and less in diameter. This is the size and type of material that makes up the mat of residue left on the ground in the thinned stands of timber.

Conclusions and Recommendations

Many results and conclusions were discussed in the preceding section. However, we believe that the most significant conclusion merits repeating: Using Potter's full-tree logging-utilization system, a landowner can thin a stand of trees with an average DBH of six inches on a break-even basis. Traditional logging techniques require trees with a minimum DBH of eight to nine inches. If the average DBH if four inches, the operation must be subsidized with approximately 2,000 board feet per acre of commercial timber.

In addition, this system has many benefits that do not appear in a direct economic evaluation. Although it is very difficult to place dollar value on these advantages, they are important. In fact, for many landowners, the indirect or future benefits may either outweigh immediate economic concerns or constitute a form of subsidy for the present operation. The indirect benefits of full-tree thinning and utilization are as follows:

1. As in any thinning program, growth rates of the residual trees will increase.
2. With virtually no logging slash left in the woods, potential damage from fire or insects is minimized. In addition, grass and forage production can be increased.
3. The stand is easily accessible for future thinning-harvesting operations.
4. Many people find the thinned, slash-free stand asthetically pleasing.

As is the case in any study, this project identified several areas for further investigation. Potter thinned his stands to remove dead and dying timber. However, in conjunction with a pretreatment stand inventory, it would be useful to be able to determine expected yields from various levels of thinning intensity. The Montana Forest and Conservation Experiment Station is currently conducting a study that should provide this needed base for yield

projections. Potter used a thinning system for small trees which emphasized building piles to the full capacity of the skidding tractor. For comparison, it may be desirable to use a system in which the felling crew does minimal bunching. However, the single stems or small piles would be prebunched on a central skidway for removal to the landing. Another alternative would be to use other low cost feller-bunchers that are designed specifically for small-diameter trees.

Although Potter's system worked very well, it is effectively limited to terrain where slopes do not exceed 15 to 20 percent. Many young timber stands in Montana are located on steeper land. We feel that a logical extension of this study would be to develop a full-tree thinning technique suitable for steep slopes. Potentially, a small, highly mobile cable yarding system could retrieve prebunched piles to a roadway or ridgetop, where a grapple-equipped tractor could forward the piles to the chipper.

In conclusion, we want to reiterate three important points for anyone contemplating a full-tree thinning and chipping operation. First, the operator must have accurate stand data to determine the size and number of trees to be removed. Second, we feel that the most critical part of the operation is a coordinated, well planned logging system. To some degree, chipping is secondary. Finally it is necessary to closely match the equipment (including the chipper) to the size of the timber.

IV MONITORING

The cooperators anticipate that this thinning-utilization system will be used more frequently in our area, particularly as traditional energy sources become more expensive. Since the completion of this study, a commercial contractor has begun a similar operation for Champion Timberlands. In addition, another logging concern is negotiating for the necessary contracts and equipment to begin work on private land. Potter is also operating on adjacent ownerships and is assisting the Lubrecht Forest with thinning projects. As indicated previously, we believe that we have the necessary baseline data and background to investigate thinning techniques suitable for steeper terrain. A preliminary study using a radio-controlled winch system and a small cable yarding system was tested in the summer of 1982 on the Lubrecht Forest. The project tested the production capabilities and economics of using non-industrial-sized systems on steeper slopes.

The names and addresses of the individuals who prepared this report are listed in the following section. Either person can be contacted for more detailed information on this project or subsequent studies.

Public Availability

The purpose of this project was to research the cost of whole-tree chipping of thinning residue. The field work portion of the project was completed in the spring of 1981: consequently, only the thinned timber stands remain on the study areas. However, Mr. Potter is doing more thinning on his and neighboring landowners' property. Individuals who are interested in viewing this type of thinning operation or who have questions about the study can contact:

Hank Goetz, Manager
Lubrecht Experimental Forest, U of M
Greenough, MT 59836
406-244-5524

or

Sherwin K. Smith
Missoula County Agricultural Stabilization
Conservation Service Office
2801 Russell
Missoula, MT 59801
406-329-3109

While the field work portion of the project was being done, the operation was observed by a great number of individuals. The following is a list of the groups that toured the project:

State Foresters
Private Landowners
Agricultural Producers
Extension Service Personnel
Missoula & Mineral County ASCS Committeemen
Western Montana ASCS County Directors and Personnel
Montana ASCS District Directors
Private Mill Operators
Private Logging Operators
Corporate Logging Company Officials
Missoula Electric Co-op Official
Lolo National Forest Personnel
SCS Personnel
RC&D Officials
FmHA Personnel
USFS Region 1 Personnel
Granite County Soil Conservation District Members
KECI TV
KPAX TV
The Missoulian

We would estimate that well over 100 people toured the project. These individuals and groups came from a geographical area that includes all of western Montana and a portion of northern Idaho. It should be noted that many more individuals and groups have toured Bill Potter's operation since the completion of the field work portion of this study.

Almost all of the people who viewed the project were impressed with the operation. Most felt that the landowner could, by using farm sized equipment, better utilize and manage their timber resource.

The project received news media coverage three different times. MTN News (KPAX TV) carried a report on the project over their TV network, and the Eagle Communications Network (KECI TV) aired a 30 minute program on the project. The Missoulian published a detailed article on the project in their newspaper on December 26, 1980.

Sherwin K. Smith, project coordinator, has given talks on the project to:

County Rural Development Committees,
Resource Conservation & Development Committees of
Missoula and Mineral and Ravalli Counties
ASCS District Meetings

Hank Goetz, manager of the Lubrecht Experimental Forest, has given talks on the project to the following groups:

American Pulp Wood Association
American Society of Agricultural Engineers
Montana Forest Industries Convention
U of M School of Forestry calsses
Missoula County Vo-Tech classes
Society of American Foresters
An informal presentation at the Forest Products Society Conference
on Small Timber Harvesting and Utilization at Syracuse, New York.

APPENDIX A

Developmental History of the Grapple System

Grapple systems have been used for many years in the logging industry. However, these systems were designed for commercial and/or industrial operations. In the past, landowners had to depend on cables and chains to pull timber and logs from the woods. This was the case with Bill Potter, a rancher from Greenough, Montana. Bill felt there had to be a better way to skid his merchantable timber from the woods using his farm equipment.

During the past 10 years, Mr. Potter has built four different grapples that attach to the three-point hitch of his farm tractor. These units, each different in size and design, were constructed entirely on a trial-and-error basis with whatever used material was available. Potter found that these grapples worked very well for skidding thinning residue from a stand of timber to a landing where it could be disposed of. Two of these grapples were used for skidding residue and pulplogs during this thinning and chipping research project.

Many landowners who observed the thinning and chipping operations requested specifications for the homemade grapples so that they could build a similar unit. Unfortunately, this information did not exist. In addition, the grapples were designed to fit Mr. Potter's specific make and model farm tractor. It was difficult for someone else to duplicate his design. Professional technical assistance was necessary to make Potter's design available to other interested parties.

The Renewable Energy Bureau of the Montana Department of Natural Resources and Conservation provided a $4,000 grant to develop professionally engineered design specifications for a low-cost set of hydraulic grapples suitable for mounting on a three-point hitch tractor. This would include detailed drawings of the grapple presented so that individuals could either build it themselves

from commonly available materials or contract the work to a local machine shop.

On March 3, 1981, the Western Montana Timber Utilization Group signed an agreement with the Forest Service Missoula Equipment Development Center (MEDC). This agreement stated that MEDC would provide engineering services to verify and/or improve the design of the last grapple Mr. Potter had designed and prepare construction drawings, specifications and parts lists for the selected design of the Farm Tractor Log-Skidding Grapple.

In conjunction with the design work, MEDC constructed a prototype grapple from their preliminary drawings and specifications. This grapple was paid for in part by a Renewable Resources Grant from DNRC.

This prototype was mounted on a 50-horsepower John Deere 2240 four-wheel drive farm tractor owned by the Lubrecht Experimental Forest. The grapple was then field tested. As problems arose during the field testing, changes were made on the drawing and specifications.

The final construction drawings, specifications and parts lists were completed in November of 1981. This grapple is designed to fit farm tractors in the 45- to 85- horsepower class with three-point hitches. The cost breakdown for this design work was as follows:

Engineering		$1500.00
Drafting and detailing		2500.00
	TOTAL	$4000.00

Changes and improvements to the design are being made as the need arises.

There are certain modifications landowners should make to a conventional farm tractor if they are going to use it in the woods. The modifications include the installation of a "belly skid pan" and special guarding for the radiator, tire valve stems, power take-off unit and front axle tie rods.

Copies of the construction drawings and specifications are available from the Missoula Equipment Development Center, USFS, Fort Missoula, Missoula, MT 59801.

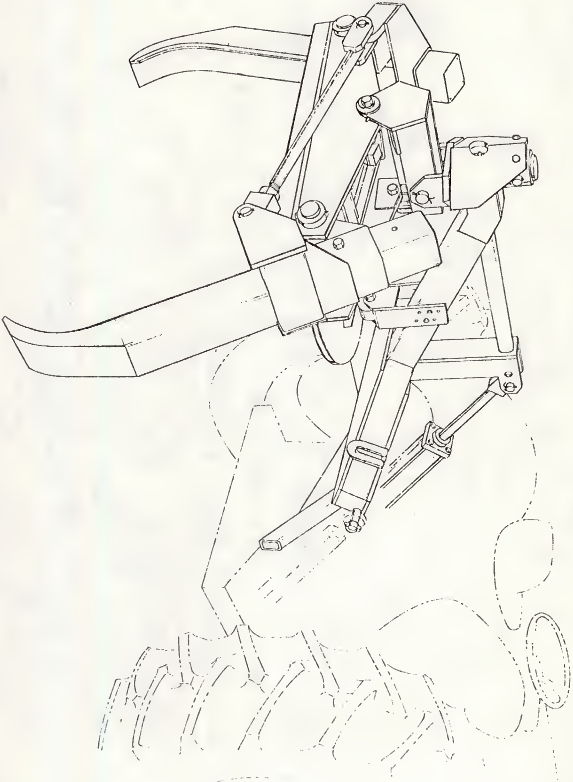

TABLE 1

Stand Data Summary

ITEM	AVERAGE VALUE	RANGE OF VALUES
1. Average Number of Stems per Acre		
Prior to Harvest	794	589 - 1726
After Harvest	252	127 - 919
2. Cubic Foot Volume of Stems Less than 8 Inches DBH		
Prior to Harvest	1360	1068 - 1655
After Harvest	116	70 - 218
3. Board Foot Volume (Scribner Dec. C) 9 Inches DBH and Larger		
Prior to Harvest	5344	1832 - 8996
After Harvest	1951	872 - 5182
4. Square Feet of Basal Area Removed per Acre	83	53 - 146

TABLE 2

Description of the Logging and Chipping System by Block

		FELLING AND BUNCHING		SKIDDING		MATERIAL HANDLING PRIOR TO CHIPPING	
Block Number	Block Size in Acres	Small Stems	Larger Stems	Small Stems	Larger Stems	Small Stems	Larger Stems
1	8.7	Hand	Hand	*AC 180,2940 440	2940,440 AC 180	Cold decked	Cold decked
2	5.0	Hand	*1075 F/B	2940,440 AC 180	2940,440	Cold decked	Cold decked
3	7.1	Hand	1075 F/B	2940,440 AC 180	2940,440	Cold decked	Cold decked
4	18.0	Hand	1075 F/B	2940,440 AC 180	440	Cold decked	Hot logged
5	39.2	None	1075 F/B	None	440	None	Cold decked & Hot logged
6a	19.4	Hand	1075 F/B	2940, AC 180	440	Cold decked	Hot logged
6b	10.2	1075 F/B	1075 F/B	2940, AC 180	440	Hot logged	Hot logged
7	20.5	Hand	1075 F/B	2940, AC 180	440	Cold decked	Hot logged
8	2.6	Hand	1075 F/B	2940 Ford 7000	2940 Ford 7000	Hot logged	Hot logged
9	2.8	825 F/B	825 F/B 1075 F/B	440	Ford 7000	Hot logged	Hot logged
10	29.6	825 F/B 1075 F/B	825 F/B 1075 F/B	Ford 7000 440	Ford 7000 440	Hot logged	Hot logged

* These are the model numbers of the machines used for the respective functions. See text for description

TABLE 3

Average Production Data by Function and Material Size Class

ITEM	AVERAGE NUMBER	RANGE
Felling and Bunching		
Material less than 6"DBH, pieces per hr.		
By hand with 3 people and 1 saw	121	106 - 149
825 F/B and 1 sawyer	108	88 - 115
825 F/B	60	--------
Material 6 - 15"DBH, pieces/hr.		
1075 F/B	58	44 - 67
1075 F/B and sawyer	98	88 - 105
Material 16"DBH and larger, board feet/hr.		
Hand felling only	1891	1082 - 5134
Skidding		
Material less than 6"DBH, pieces/hr.		
AC 1980 tractor with grapple	200	131 - 246
JD 2940 tractor with grapple	229	208 - 257
JD 440 rubber tired skidder	271	227 - 359
Material 6 -15"DBH, pieces/hr.		
JD 440	43	27 - 61
Material 16"DBH and larger, BF/hr.		
JD 440	2720	2163 - 3426
Processing		
Commercial logs less than 15"DBH, BF/hr.		
Per crew member hour	1066	632 - 1831
Per machine hour (JD 2940)	2600	--------
Commercial logs greater than 15"DBH, BF/hr.		
Per crew hour	2390	2162 - 2567
Per machine hour (JD 440)	3494	2162 - 6418
Chipping (Morbark Model 12 Chiparvestor)		
Green tons per net chipping hour	11.11	9.23 - 14.12
Green tons per system day	55.31	47.48 - 64.40
Units per net chipping hour	8.79	7.42 - 10.75
Units per system day	43.76	35.58 - 49.03
Net chipping time per van in hours	1.81	1.55 - 2.13
Gross chipping time per van in hours	1.95	1.55 - 2.67
Average number of vans per system day	2.75	2.31 - 3.06

TABLE 4

Yield Measurement Relationships and Yield per Acre Data

ITEM		AVERAGE NUMBER	RANGE
Yield Relationships			
Number of pounds per unit		2,528	2,015 - 2,799
Number of pieces per unit		36	16 - 63
Number of pieces per ton		28	12 - 48
Piece size in cubic feet		2.21	1.27 - 5.00
Number of tons per 40 foot van		20.116	16.21 - 23.42
Number of units per 40 foot van		15.92	14.69 - 17.83
Yields Per Acre			
Pieces removed per acre			
Five inches DBH and smaller		425	300 - 790
Six to eight inches DBH		70	9 - 133
Nine inches DBH and greater		38	8 - 44
	TOTAL	542	452 - 821
Yield per acre			
Green weight tons		21.061	16.192 - 46.936
200 cubic foot units		16.58	12.44 - 35.58
Board feet, Scribner Rule		3,356	420 - 6,197

TABLE 5

Hourly Equipment Rates

Machine	Fixed Cost per Hour	Operational Cost per Hour	Total Cost per Hour
Morbark Model 12 Chiparvestor	$10.71	$14.94	$25.65
John Deere Model 440 Rubber Tired Skidder	9.16	8.26	17.42
Melroe Model 1075 Feller/Buncher	9.50	8.09	17.59
Melroe Bobcat Model 825 Feller/Buncher	2.99	3.41	6.40
John Deere Model 2940 4WD Farm Tractor	2.94	4.11	7.05
AC 180 and Ford 7000 Farm Tractors	2.71	3.55	6.26
Chainsaws	---	---	1.50

TABLE 6

Logging and Processing Hourly Rates by Function

Function	Machinery and Labor Components	Total System Cost per Hour
FELLING AND BUNCHING		
Hand thinning	3 people and 1 chainsaw	$24.00
Machine thinning	825 F/B and operator	13.90
	1075 F/B and operator	29.59
Combination systems	825 F/B, operator, sawyer, saw	22.90
	1075 F/B, operator, sawyer, saw	38.59
SKIDDING		
	AC 180 or Ford 7000 with operator	13.76
	JD 2940 with operator	14.55
	JD 440 with operator	29.42
PROCESSING		
Handbucking and limbing	Sawyer and chainsaw	9.00
Chipping	Morbark Model 12 and operator, JD 2940 and operator, clean-up person	59.70

TABLE 7

Production Costs by Function and Material Size Class

Function	Average Cost	Range
FELLING AND BUNCHING		
Trees 5" DBH and smaller, cost/piece		
Hand thinning system	19.8¢	16.1 - 22.6¢
825 and operator	23.2¢	------------
825, operator and sawyer	21.2¢	19.9 - 26.0¢
Trees from 6 - 15" DBH, cost/piece		
1075 and operator	51.0¢	44.2 - 67.2¢
1075, operator and sawyer	39.4¢	36.8 - 43.9¢
Trees 16" DBH and greater, cost/MBF		
Hand felling	$6.35	$2.34 - $11.09
SKIDDING		
Trees 5" DBH and smaller, cost/piece		
AC 180 tractor and operator	6.9¢	5.6 - 10.5¢
JD 2940 tractor and operator	6.4¢	5.7 - 7.0¢
JD 440 skidder and operator	10.9¢	8.2 - 13.0¢
Trees from 6 - 15" DBH, cost/piece		
JD 440 skidder and operator	68.4¢	$.48 - $1.09
Trees 16" DBH and greater, cost/MBF		
JD 440 skidder and operator	$10.82	$8.59 - $13.60
PROCESSING		
Commercial trees less than 15" DBH		
Per crew member, cost/MBF	$8.44	$4.92 - $14.24
Per machine and operator, cost/MBF	$5.60	-----------
Commercial trees 16" DBH and larger		
Per crew member, cost MBF	$3.77	$3.51 - $4.16
Per machine and operator, cost MBF	$8.42	$4.58 - $13.61

TABLE 7 (CONTINUED)

Production Costs by Function and Material Size Class

Function	Average Cost	Range
CHIPPING		
Based on a net chipping hour		
Cost per green ton	$ 5.37	$ 4.23 - 6.47
Cost per unit	6.79	5.55 - 8.05
Based on a system day		
Cost per green ton	7.56	6.49 - 8.80
Cost per unit	9.55	11.75 - 8.52
Cost per van load		
Based on net chipping time	108.06	92.54 - 127.16
Based on gross chipping time	116.42	92.54 - 159.4[illegible]
Based on system day	151.96	136.57 - 196.20

TABLE 8

Summary of the Volume Removals, Costs and Income on a Per Acre Basis for the Individual Treatment Blocks

ITEM	BLOCK NUMBER 1	2	3	4	6	7	8	9	10
VOLUME DATA									
No. of pcs. removed	807	821	546	749	370	667	579	700	452
No. of units removed	12.9	14.4	12.4	12.8	17.1	16.1	35.5	35.6	18.2
MBF removed	.42	3.82	1.74	3.89	6.20	4.10	1.35	1.59	1.35
No. of pcs. per units	63	57	44	58	22	33	16	20	26
Ave. pc. size in cubic ft.	1.27	1.40	1.82	1.38	3.69	2.42	5.0	4.0	3.08
COSTS IN $									
Trees 5" DBH and smaller	181	220	148	190	116	114	127	168	84
Trees 6-15" DBH	20	105	92	94	182	148	117	47	158
Trees 16"DBH and larger	---	23	---	28	15	11	---	---	---
Total logging costs	201	348	240	312	313	273	244	215	242
Chipping costs	144	134	118	151	155	143	289	278	169
TOTAL COSTS	345	482	358	463	468	416	533	493	411
REVENUE in $									
Hog fuel	193	216	187	193	256	241	532	535	265
Logs	34	379	139	379	565	395	118	120	108
TOTAL REVENUE	227	595	326	572	821	636	650	655	373
NET REVENUE	(-118)	113	(-32)	109	353	220	117	162	(-38)

CREDITS

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Western Montana Timber Utilization Group,
Sherwin K. Smith, Project Coordinator
Missoula, Mt.

#1

3 2 1

MATERIALS LIST

NO	PART NAME	REQD	MATERIAL-DESCRIPTION	SHEET
1	FRAME	1	PARTS 2-25	2 & 3
26	ROLLER HOUSING	1	PARTS 27-28	2 & 3
29	CAM FOLLOWER	1	TORRINGTON # YCRS-40 OR EQUAL	
30	BOLT	1	3/4-10NC × 3 LG HEX HD BOLT	
31	NUT	7	3/4-10NC FIBER LOCK HEX NUT	
32	BOLT	4	3/8-16NC × 6 LG HEX HD BOLT	
33	MOUNTIN PLATE	1	PARTS 34-44, 90-91	4
45	SWIVEL PIN	1	PARTS 46-50	5
51	HANGER	1	PARTS 52-57	5
58	CAP	1	PARTS 59-60	5
61	CAP PIN	1	PART 61	5
62	RH TOOL HOLDER	1	PARTS 63-70	6
71	BEARING	4	OILITE # AA-2204-1 (2 × 2 1/2 × 2 LG) OR EQ	
72	PIVOT PIN	2	PART 72	6
73	CLEVIS PIN I	1	PART 73	6
74	CLEVIS PIN II	1	PART 74	6
75	LH TOOL HOLDER	1	PARTS 76-84	7
85	PIN	2	7/16 DIA LINCH PIN	
86	CYLINDER END	1	PARTS 87-88	7
89	BUSHING	2	PART 89	7
92	HANGER PIN	1	PART 92	5
93	BOLT	2	3/4-10NC × 2 3/4 LG HEX HD BOLT	
94	BOLT	4	3/4-10NC × 6 LG HEX HD BOLT	
95	BOLT	4	1/4-20NC × 3 1/2 LG HEX HD BOLT	
96	BOLT	2	1/2-13NC × 1 1/2 LG HEX HD BOLT	
97	TOOL ARM	2	PARTS 98-101	8
102	NUT	1	1 1/4-7NC HEX NUT	
103	CONNECTING ROD	1	PARTS 104-105	8
106	ROD END	1	PART 107-108	8
109	COTTER PIN	14	1/8 DIA × 2 LG COTTER PIN	
110	WASHER	14	3/4 DIA PLAIN WASHER	
111	WASHER	6	1 DIA PLAIN WASHER	
112	WASHER	2	1 1/2 DIA PLAIN WASHER	
113	WASHER	4	3/8 DIA PLAIN WASHER	
114	WASHER	2	1/2 DIA LOCK WASHER	
115	GREASE FITTING	7	ALLIMITE # 1792-B OR EQUAL	
116	NUT	4	1/4-20NC FIBER LOCK NUT	
117	NUT	2	3/8-16NC FIBER LOCK NUT	
118	CYLINDER	1	PRINCE # PMC-9312 (3 1/2 DIA × 12 ST) OR EQ	
119	CYLINDER	1	PRINCE # PMC-9212 (3 DIA × 12 ST) OR EQ	

D

C

NOTES:
1 RUBBER STOPS MAY BE MADE FROM TIRE TREADS. FASTEN WITH SCREWS IF POSSIBLE SO THEY DO NOT SLIP OFF PADS

B

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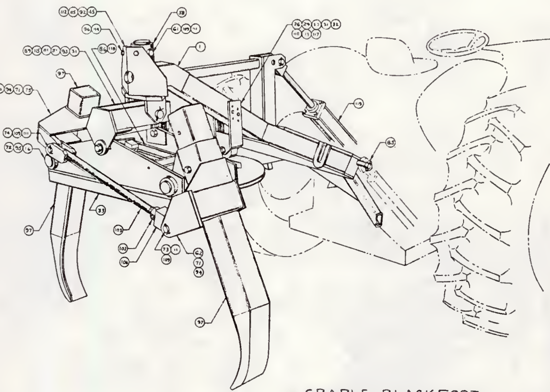
#1A



GRAPLE, BLACKFOOT

NO	PART NAME	QTY
1	FRAME	
26	ROLLER HOUSING	
29	CAM FOLLOWER	
30	BOLT	
31	NUT	7
32	BOLT	4
33	MOUNTING PLATE	
45	SWIVEL PIN	1
51	HANGER	1
58	CAP	
61	CAP PIN	1
62	RH TOOL HOLDER	1
71	BEARING	4
72	PIVOT PIN	2
73	CLEVIS PIN I	1
74	CLEVIS PIN II	1
75	LH TOOL HOLDER	1
85	PIN	2
86	CYL HOSE END	1
89	BUSHING	2
92	HANGER PIN	
93	BOLT	2
94	BOLT	4
95	BOLT	4
96	BOLT	2
97	TOOL ARM	2
102	NUT	1
103	CONNECTING ROD	
104	ROD END	1
109	COTTER PIN	19
110	WASHER	14
111	WASHER	6
112	WASHER	2
113	WASHER	8
114	WASHER	2
115	GREASE FITTING	7
116	NUT	4
117	NUT	2
118	CYLINDER	1
119	CYLINDER	

NOTES:
1 RUBBER STOPS ... FASTEN WITH ... NOT SLIP OFF ...

TOLERANCES
FRACTIONS ±
DECIMALS ±
ANGLES ±

DRAWN LASS
DESIGNED
CHECKED
APPROVED
SCALE NONE
DATE NOV 1991

#2

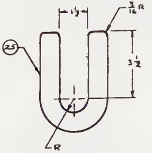
2		1	

MATERIALS LIST

NO	PART NAME	REQD	MATERIAL-DESCRIPTION	SHEET
1	FRAME	1	PARTS 2-25	
2	BEAM	1	4 x 4 x 1/4 SQ STEEL TUBE	
3	TEE	1		
4	NECK	1		
5	BRACE	2		
6	PIVOT	1	4 1/2 OD x 3/4 WALL x 6 LG ROUND STL MECH TUBE	
7	PLATE, SIDE	2	1/4 THICK 1020 HR STEEL PLATE	
8	PLATE, TOP	1		
9	PLATE, BOTTOM	1		
10	LOWER HITCH PIN	2	1 1/8 OD 1045 CR STEEL ROUND	
11	END CAP	2	1/2 x 4 x 4 LG 1020 HR STL FLAT	
12	INNER PLATE	2	1/2 x 3 1/2 x 3 1/2 LG 1020 HR STL FLAT	
13	UPPER HITCH PT	2	3/8 x 3 x 6 LG 1020 HR STL FLAT	
14	UPRIGHT	2	3/8 x 3 x 11 3/16 LG 1020 HR STL FLAT	
15	BACK	1	1/2 x 3 1/2 x 12 LG 1020 HR STL FLAT	
16	BRACE	1	2 x 2 x 1/4 WALL SQ STEEL TUBE	
17	HEEL	2	2 x 2 x 1/4 WALL SQ STEEL TUBE	
18	SPACER	1	1/4 x 2 x 35 LG 1020 HR STEEL FLAT	
19	FRONT	2	1/4 THICK 1020 HR STL PLATE	
20	BACK	1	1/4 THICK 1020 HR STL PLATE	
21	STOP	2	2 x 2 x 1/4 WALL SQ STL TUBE	
22	SPACER	2	3/8 SCH 40 x 4 LG PIPE	
23	BEARING (BOTTOM)	1	OILITE #AA-3200 (3 x 3 1/2 x 2 LG) OR EQUAL	
24	BEARING (TOP)	1	OILITE #AA-3200-2 (3 x 3 1/2 x 3 LG) OR EQUAL	
25	HOOK	2	1.00 1020 HR STEEL ROUND	
26	ROLLER HOUSING	1	PARTS 27-28 SEE SHEET 3	
27	SIDE	2	3/8 x 3 1/2 x 7 1/4 LG 1020 HR STEEL FLAT	
28	CROSS	2	1/4 THICK 1020 HR STEEL PLATE	

D

C



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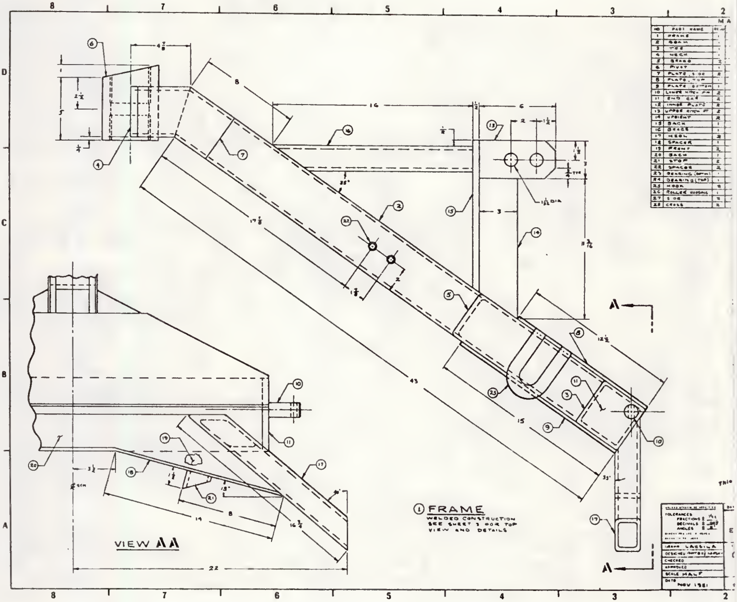
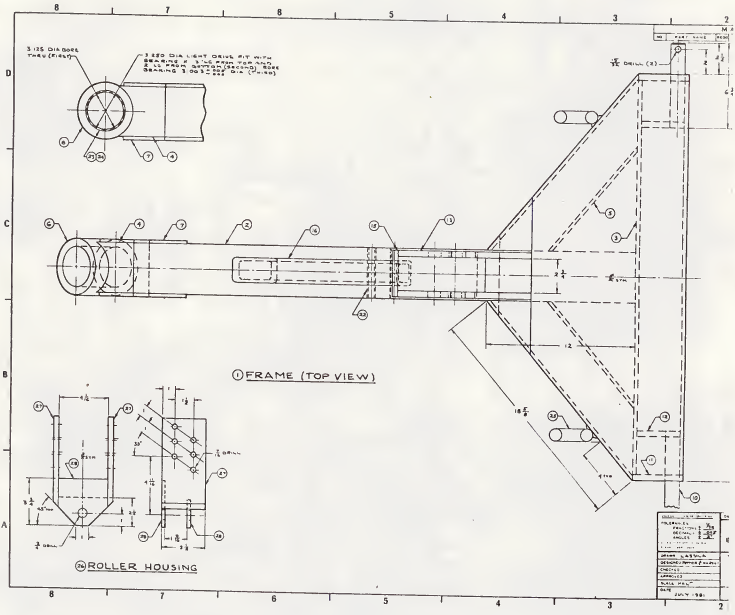


FRAME
WELDED CONSTRUCTION
SEE SHEET 3 FOR TOP
VIEW AND DETAILS
VIEW AA
A
A
NO
PART NAME
1 FRAME
2 BEAM
3 TEE
4 NECK
5 BRACE
6 PIVOT
7 PLATE, SIDE
8 PLATE, TOP
9 PLATE, BOTTOM
10 LOWER HITCH PIN
11 END CAP
12 INNER PLATE
13 UPPER HITCH PT
14 UPRIGHT
15 BACK
16 BRACE
17 HEEL
18 SPACER
19 FRONT
20 BACK
21 STOP
22 SPACER
23 BEARING (BOTTOM)
24 BEARING (TOP)
25 HOOK
26 ROLLER HOUSING
27 SIDE
28 CROSS
TOLERANCES
FRACTIONS
DECIMALS
ANGLES
DRAWN LAESILA
DESIGNED
CHECKED
APPROVED
SCALE HALF
DATE NOV 1981

#3


3.125 DIA BORE THRU (FIRST)
3.250 DIA LIGHT DRIVE FIT WITH BEARING X 3" LG FROM TOP AND 2 LG FROM BOTTOM (SECOND) BORE BEARING 3.003 DIA (THIRD)
① FRAME (TOP VIEW)
㉖ ROLLER HOUSING
12
18 5/8
45° TYP
35°
7/16 DRILL
3/4 DRILL
TOLERANCES
DRAWN LASSILA
CHECKED
APPROVED
SCALE HALF
DATE JULY 1981

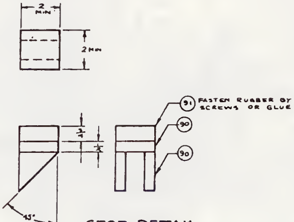
#4

2 1

MATERIALS LIST

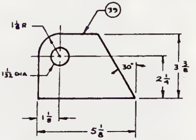
NO	PART NAME	REQD	MATERIAL-DESCRIPTION	SHEET
33	MOUNTING PLATE	1	PARTS 34-44, 90-91	
34	PLATE	1	1/2 THICK 1020 HR STEEL PLATE	
35	UPRIGHT	2	1/2 x 8 x 40 LG 1020 HR STEEL FLAT	
36	SPACER	2	3/8 x 3 x 5 LG 1020 HR STEEL FLAT	
37	PIVOT COLLAR	4	300 x 210 x 1 LG 1045 ROUND STEEL TUBE	
38	BRACE	3	1/2 x 4 x 14 LG 1020 HR STEEL FLAT	
39	CYLINDER MT	1	1 x 3 3/8 x 5 1/8 LG 1020 HR STEEL FLAT	
40	BRACE	1	1/2 THICK 1020 HR STEEL PLATE	
41	TOP BRACE	1	1/2 x 2 x 11 LG 1020 HR STEEL FLAT	
42	CYLINDER STOP	1	1 x 1 x 1 1/8 LG 1020 HR STEEL FLAT	
43	STIFFENER	2	1/2 x 2 x 40 LG 1020 HR STEEL FLAT	
44	BRACE PLATE	1	1/2 x 5 1/2 x 5 1/2 LG 1020 HR STEEL FLAT	
90	STOP MOUNT	2	1/2 x 2 1020 HR STEEL FLAT	
91	STOP	2	3/4 THICK RUBBER	

D



C

STOP DETAIL



B

(39) CYLINDER MOUNT

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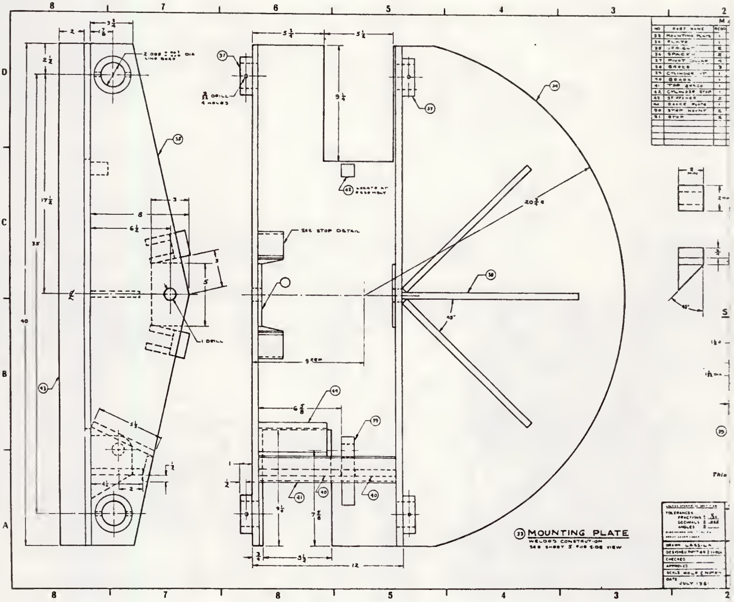


MOUNTING PLATE
WELDED CONSTRUCTION
SEE SHEET 5 FOR SIDE VIEW
TOLERANCES
FRACTIONS
DECIMALS
ANGLES
DRAWN LASSILA
CHECKED
APPROVED
SCALE
DATE JULY 1961
PART NAME
MOUNTING PLATE
PLATE
SPACER
PIVOT
BRACE
TOP BRACE
STOP MOUNT
STOP
SEE STOP DETAIL
1 DRILL

#44

#5

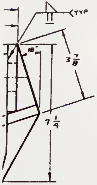
2		1	

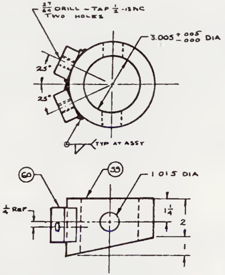
MATERIALS LIST

NO	PART NAME	REQD	MATERIAL-DESCRIPTION	SHEET
45	SWIVEL PIN	1	PARTS 46-50	
46	PIN	1	300 X 10 LG 1045 CR STEEL ROUND	
47	PLATE	1	1 X 5½ X 11⅛ LG 1020 HR STEEL FLAT	
48	EAR	2	¾ X 4¼ X 5½ LG 1020 HR STEEL FLAT	
49	STOP PLATE	2	¾ THICK 1020 HR STEEL PLATE	
50	STOP	2	¾ THICK X 2 SQ MIN RUBBER	
51	HANGER	1	PARTS 52-57	
52	TOP	1	½ X 4 X 12⅝ LG 1020 HR STEEL FLAT	
53	SIDE	2	½ X 3½ X 12⅝ LG 1020 HR STEEL FLAT	
54	EAR	2	¾ THICK 1020 HR STEEL PLATE	
55	SPACER	2	¼ THICK X 300 1020 HR STEEL PLATE	
56	STOP	2	½ X 2 X 2¾ LG 1020 HR STEEL FLAT	
57	BEARING	2	OILITE # AA1512-15 (1½ X 1⅞ LG) OR EQUAL	
58	CAP	1	PARTS 59-60	
59	CAP	1	4½ OD X ¾ WALL MECH RD TUBE	
60	PADS	2	¾ X 1½ X 1½ LG 1020 HR STEEL FLAT	
61	CAP PIN	1	1 DIA 1045 CR STEEL ROUND	
92	HANGER PIN	1	1½ DIA 1045 CR STEEL ROUND	

D

IN





C

(58) CAP

B

#3 DRILL ~ TAP 1/4-28NF

.500 DIA LIGHT PRESS
FIT WITH BEARING

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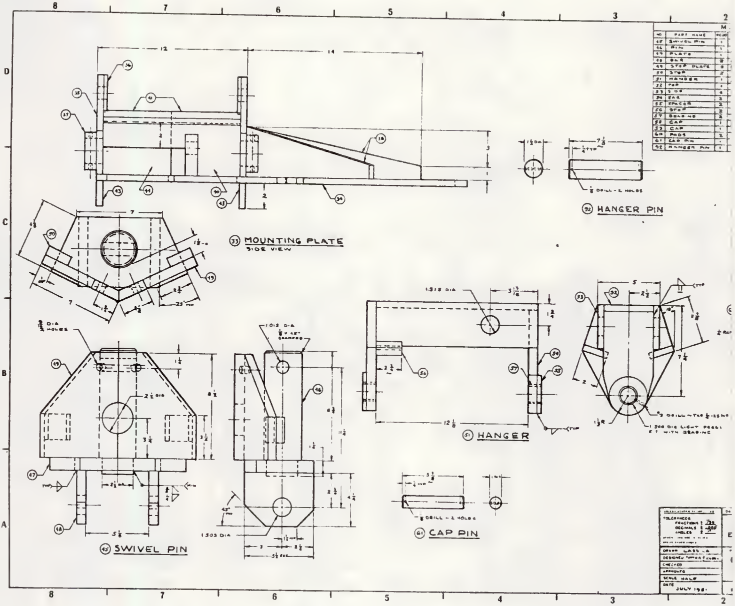


MOUNTING PLATE
SIDE VIEW
HANGER PIN
HANGER
SWIVEL PIN
CAP PIN
PART NAME
SWIVEL PIN
PLATE
BAR
STOP PLATE
STOP
HANGER
CAP
PADS
CAP PIN
HANGER PIN
DRAWN
DESIGNED
CHECKED
APPROVED
SCALE HALF
DATE
JULY 196

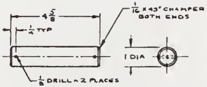
#5A

#6

MATERIALS LIST

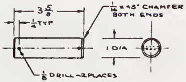
NO	PART NAME	REQD	MATERIAL DESCRIPTION	SHEET
62	RH TOOL HOLDER	1	PARTS 63-70	
63	TUBE	1	5 x 5 x 1/4 x 12 LG SQ MECH TUBE STEEL	
64	BRACE (TOP)	3	3/8 x 4 1/2 x 12 LG 1020 HR STEEL FLAT	
65	PIVOT HOUSING	1	3 00 x 7/16 WALL x 11 LG ROUND MECH TUBE CD STL	
66	ARM	1	4 1/2 x 4 1/2 x 1/4 x 9 1/4 LG SQ MECH TUBE STL	
67	END PLATE	1	3/4 x 5 1/2 x 5 1/2 LG 1020 HR STEEL FLAT	
68	EAR	1	3/4 x 5 1/2 4 1/2 LG 1020 HR STEEL FLAT	
69	CAP	1	1/4 x 1 1/2 x 5 LG 1020 HR STEEL FLAT	
70	BRACE	1	3/8 x 4 x 9 1/2 LG 1020 HR STEEL FLAT	
72	PIVOT PIN	2	2 OD x 14 1/2 LG 1045 CR STEE ROUND	
73	CLEVIS PIN I	1	1 OD x 4 5/8 LG 1045 CR STEEL ROUND	
74	CLEVIS PIN II	1	1 OD x 3 5/8 LG 1045 CR STEEL ROUND	

D



(73) CLEVIS PIN I

C



B

(74) CLEVIS PIN II

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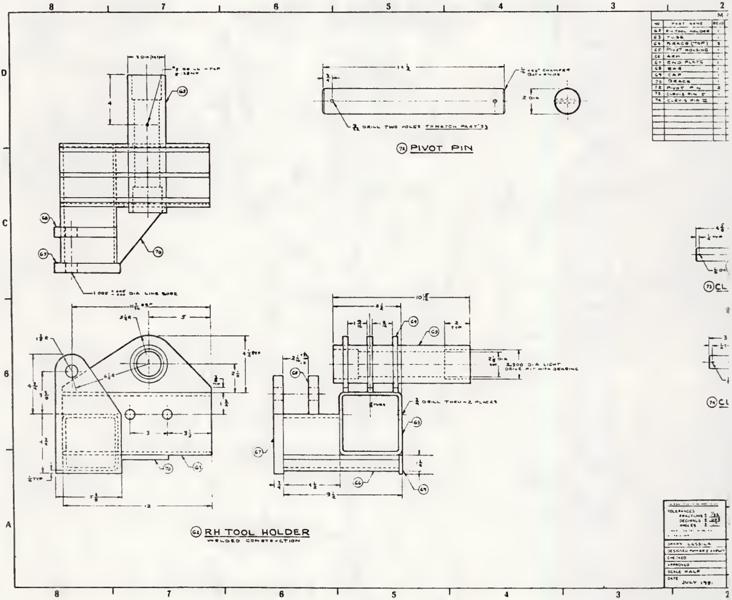
#6A


72 PIVOT PIN
$\frac{7}{32}$ DRILL TWO HOLES TO MATCH PART 73
2 DIA
14 $\frac{1}{2}$
62 RH TOOL HOLDER
WELDED CONSTRUCTION
$\frac{3}{4}$ DRILL THRU 2 PLACES
2.500 DIA LIGHT DRIVE FIT WITH BEARING
10 $\frac{1}{16}$
9 $\frac{1}{2}$
12
73 CL
74 CL
NO | PART NAME | REQD
62 | RH TOOL HOLDER | 1
63 | TUBE | 1
64 | BRACE (TOP) | 3
65 | PIVOT HOUSING | 1
66 | ARM | 1
67 | END PLATE | 1
68 | BAR | 1
69 | CAP | 1
70 | BRACE | 1
72 | PIVOT PIN | 2
73 | CLEVIS PIN I | 1
74 | CLEVIS PIN II
TOLERANCES
FRACTIONS ± 1/32
DECIMALS ± .005
ANGLES ±
DRAWN LASSILA
CHECKED
APPROVED
SCALE HALF
DATE JULY 1991

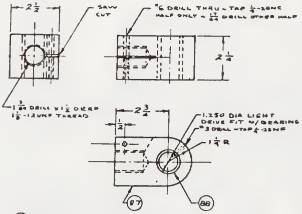
#7

2 1

MATERIALS LIST

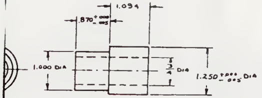
NO	PART NAME	REQD	MATERIAL DESCRIPTION	SHEET
75	LH TOOL HOLDER	1	PARTS 76-84	
76	TUBE	1	5 x 5 x 1/4 x 13 1/16 LG SQ MECH STEEL TUBE	
77	CYLINDER MT	2	1/2 x 8 1/2 x 13 5/16 LG 1020 HR STEEL FLAT	
78	BRACE (TOP)	1	1/2 x 4 3/4 x 13 1/16 LG 1020 HR STEEL FLAT	
79	PIVOT HOUSING	1	3 OD x 7/16 WALL x 11 LG ROUND STEEL TUBE	
80	BRACKET	1	1/2 x 9 x 12 3/8 LG 1020 HR STEEL FLAT	
81	BRACKET	1	1/2 x 8 x 7 3/4 LG 1020 HR STEEL FLAT	
82	END	1	1 x 2 1/2 x 8 5/16 LG 1020 HR STEEL FLAT	
83	BRACE	1	1/2 x 2 1/4 x 5 1/4 LG 1020 HR STEEL FLAT	
84	BOTTOM	1	1/4 x 2 x 8 1/2 LG 1020 HR STEEL FLAT	
86	CYLINDER END	1	PARTS 87-89	
87	END	1	2 1/4 x 2 1/2 x 4 LG 1020 HR STEEL FLAT	
88	BEARING	1	OILITE # AA-1212-5 (1 x 1 1/4 x 2 1/4 LG) OR EQUAL	
89	BUSHING	2	1 1/4 OD x 1/8 WALL DOM STEEL TUBING	

D



C

(86) CYLINDER END



B

(89) BUSHING

FULL SCALE

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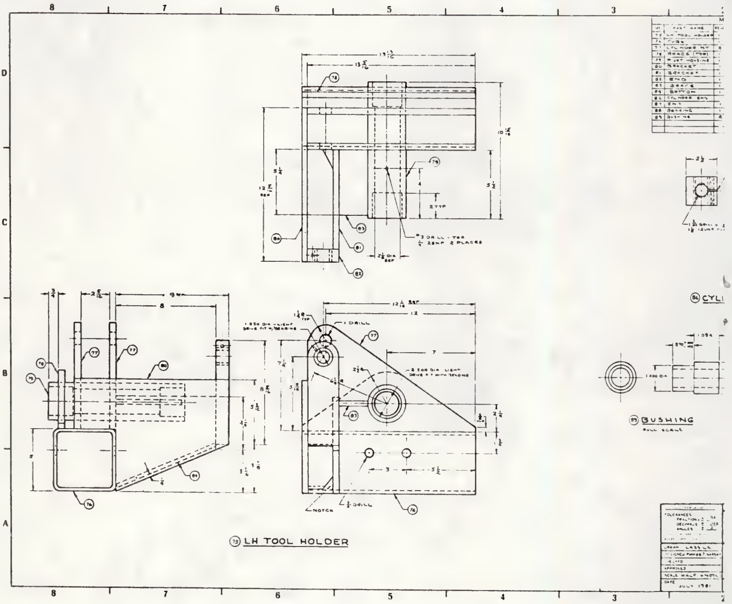
#7A



LH TOOL HOLDER
BUSHING
FULL SCALE
CYLI
1.650 DIA LIGHT DRIVE FIT W/BEARING
2.500 DIA LIGHT DRIVE FIT WITH BEARING
1 DRILL
NOTCH
3 DRILL THRU 1/4 20NF 2 PLACES
2 TYP
1.600 DIA
1.094
TOLERANCES
FRACTIONS
DECIMALS
ANGLES
SCALE HALF SIZE
DATE JULY 1981

#8

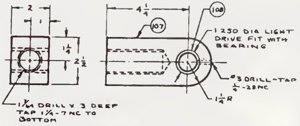
2 1

MATERIALS LIST

NO	PART NAME	REQD	MATERIAL DESCRIPTION	SHEET
97	TOOL ARM	2	PARTS 98-101	
98	TUBING	2	4 1/2 x 4 1/2 x 1/4 x 33 LG SQ MECH STEEL TUBE	
99	TOOTH	2	1/4 1020 HR STEEL PLATE	
100	SPACER	8	1 OD x 11 GA (.120) WALL x 4 1/2 LG ROUND STL TUBE	
101	RIB	2	3/8 x 3/4 x 28 1/2 LG 1020 HR STEEL FLAT	
103	CONNECTING ROD	1	PARTS 104-105	
104	ROD	1	1 1/4 OD x 30 1/4 LG 1020 HR STEEL ROUND	
105	END	2	3/4 x 2 1/4 x 5 3/8 LG 1020 HR STEEL FLAT	
106	ROD END	1	PARTS 107-108	
107	END	1	2 x 2 1/2 x 5 1/2 LG 1020 HR STEEL FLAT	
108	BEARING	1	1 1/4 OD x 1 ID x 2 LG OILITE #AA-1213 OR EQUAL	

D

C



106 ROD END

B

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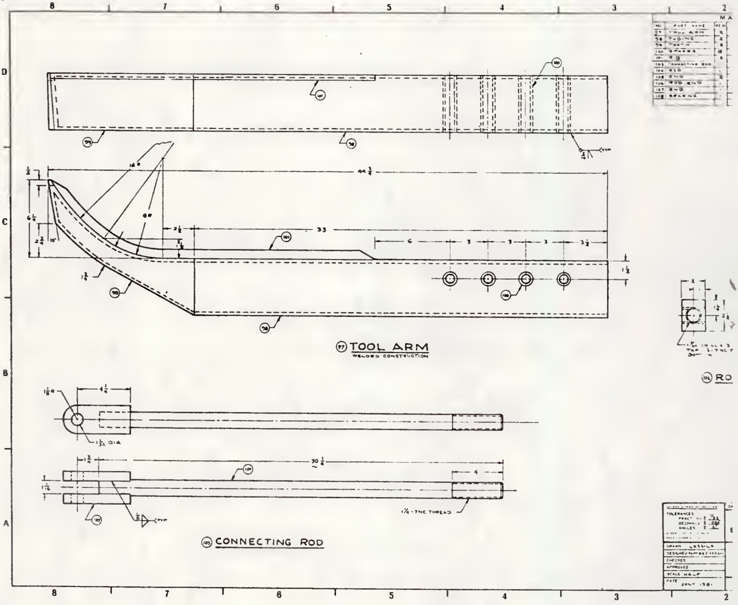
#8A



TOOL ARM
WELDED CONSTRUCTION
CONNECTING ROD
44 3/4
33
6
3
3
3
3 1/2
16 R
8 R
6 1/4
2 3/4
2 1/2
1 3/4
1 1/2
4 1/4
30 1/4
4
1 1/4 - 7NC THREAD
1 3/4
1 1/32 DIA
NO.
PART NAME
TOOL ARM
TUBING
TOOTH
SPACER
ROD
CONNECTING ROD
END
ROD END
BEARING
TOLERANCES
ANGLES
DRAWN CASSILA
CHECKED
APPROVED
SCALE HALF
DATE JULY 1981
RO

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